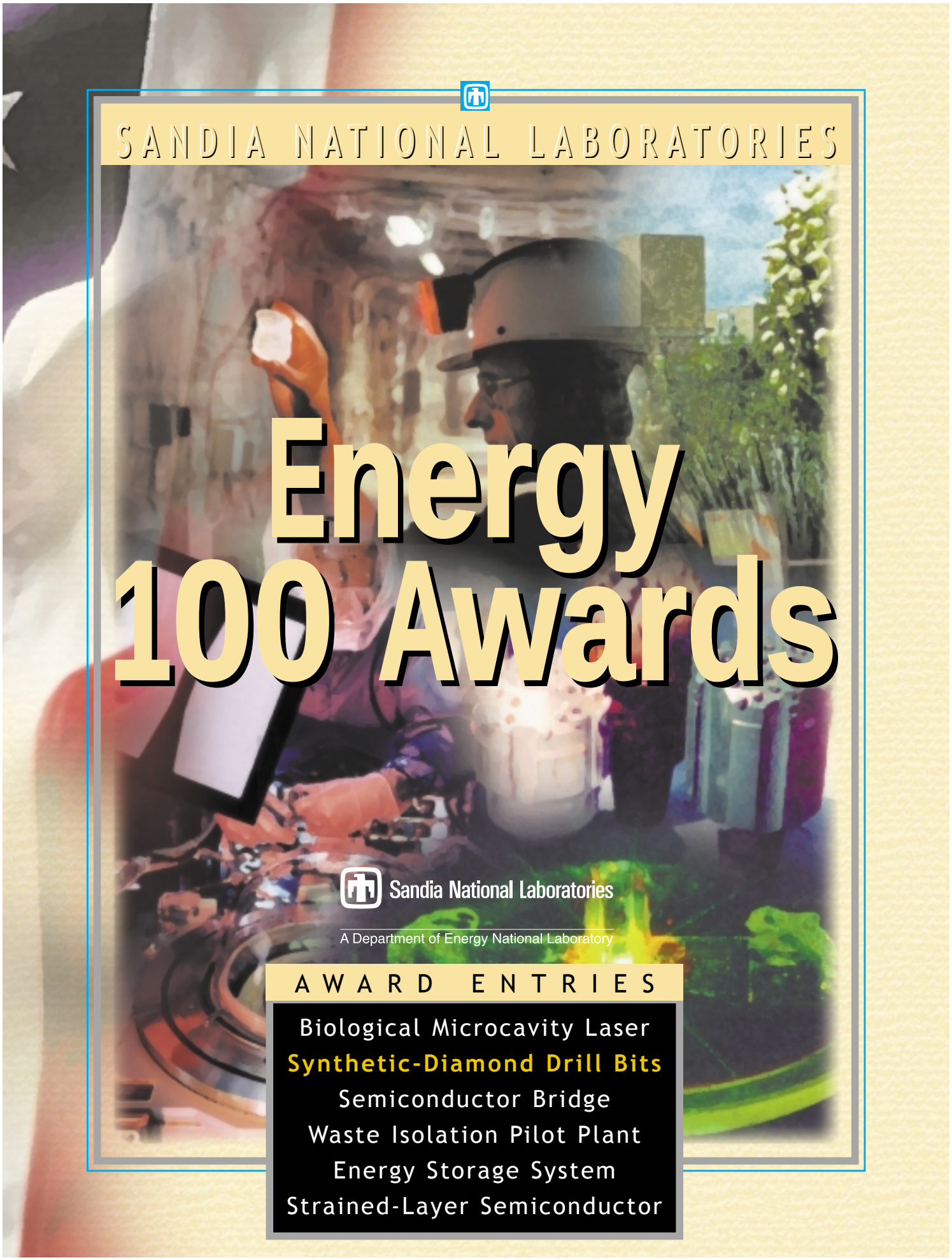
SANDIA NATIONAL LABORATORIES



Energy 100 Awards

Sandia National Laboratories

A Department of Energy National Laboratory

AWARD ENTRIES

Biological Microcavity Laser

Synthetic-Diamond Drill Bits

Semiconductor Bridge

Waste Isolation Pilot Plant

Energy Storage System

Strained-Layer Semiconductor

Synthetic-Diamond Drill Bits

Energy 100 Award Nomination
Technology: Oil, Gas, and Geothermal Drilling
Title: Synthetic-Diamond Drill Bits

Sandia National Laboratories
Submitted by: S. G. Varnado, Director
Energy and Critical Infrastructure Center
Phone: (505) 845-9555
e-mail: sgvarna@sandia.gov

Sandia's work helped pioneer a much broader range of applications for PDC bits.

ABSTRACT

Sandia National Laboratories played a major role in developing revolutionary polycrystalline diamond compact (PDC) drag bits that have captured one-third of the worldwide bit market, with annual sales exceeding $200 million. These bits exhibit greatly improved penetration rate and longevity, yielding significant cost reductions for oil, gas, and, potentially, geothermal drilling. Supporting an industry frustrated by persistent PDC failures, Sandia analyzed failure mechanisms, created robust bit designs, and catalyzed the use of PDC bits in fragmented and harder rock. A university study determined a benefit-to-cost ratio for Sandia's effort of 125-to-1, demonstrating extraordinary payback to the nation for DOE's investment.

1. Program Description

First developed by General Electric in the 1970s, PDC cutters feature thin, synthetic-diamond layers bonded to tungsten carbide supports. Multiple cutters are mounted on the surface of a drag bit. Having no moving parts, drag bits eliminate the problems of bearing and seal failures that are pervasive when drilling hot formations with roller bits. As an additional benefit, drag bits break rock in a shearing process that is inherently more efficient than the crushing process of roller bits.

By 1975, drillers used PDC drag bits in soft formations in the North Sea, but cutter failures limited attempts to penetrate hard rock. Beginning in the late 1970s, Sandia, sponsored by DOE's Geothermal Program, worked with bit manufacturers and geothermal operators to develop and test hard-rock PDC bits. Design deficiencies were identified and corrected. Basic bit design principles were determined. Laboratory and field testing demonstrated that Sandia-designed PDC bits drilled harder rocks, which translated into more efficient energy recovery and a much larger market for drag bits than previously envisioned.

In 1986, Sandia released PDCWEAR, a software code that predicts individual cutter forces and integrates those forces to produce net bit operating parameters such as weight-on-bit,

drilling torque, bending moment, and side force. The code also predicts cutter temperatures and wear, and numerically modifies cutter geometries to account for wear. Bits designed with the code last longer and drill faster, with less wobble and vibration.

Sandia continues to conduct cost-shared studies with industry partners to improve the hard-rock capability of PDC drill bits for an expanding range of applications. These bits provide significant drilling cost reductions by virtue of more rapid rock penetration and longer bit life. Co-sponsored by the DOE's Geothermal Program, DOE's Office of Fossil Energy, and multiple industry partners, the program fosters innovative approaches for enhancing hard-rock penetration.

2. Improving Quality of Life

As the world's oil supplies run low and the demand for natural gas and geothermal resources increases, energy companies must explore new, deeper formations to sustain the nation's quality of life. Sandia's research helps extend the application of PDC drag bits from soft to hard rock, assuring that the nation's energy supplies will meet demand. PDC drag bits greatly reduce the cost per well and expand the number of productive drilling sites by enabling faster and deeper drilling. Reducing prices at the wellhead for oil, gas, or geothermal energy by only a fraction of one percent saves the nation hundreds of millions of dollars per year.

Sandia's contributions to PDC bit technology helped prevent more than 3,000 lost-time accidents in a single 10-year period.

For energy production companies, record-setting PDC bit life and penetration rates (see *Other Noteworthy Benefits*) reduce the number of "trips" per well. A trip occurs when the drilling shaft is withdrawn for bit maintenance or replacement. Trips are hazardous, time-consuming, manpower-intensive operations. A study conducted by the University of New Mexico estimated that, from 1982 to 1992, Sandia's contribution to reductions in drilling time via improved PDC bits effectively prevented more than 3,000 lost-time accidents.

3. Cost Savings

Energy production companies save millions of dollars in drilling costs annually with PDC bits. The greatest factor in drilling cost is time. Drilling crews and rigs cost several tens of thousands of dollars per day for onshore work and several hundreds of thousands of dollars per day offshore. The

savings in drilling costs using a PDC drag bit often exceed $200,000 per well. One conservative estimate places the total economic benefit derived from PDC bit sales, regional economic impact, and drilling cost savings at $1.86 billion for the decade ending 1992 (in 1987 dollars).

Sandia, working with its industry and university partners, is pursuing additional possibilities for cost savings. For example, the capability of penetrating hard-rock stringers with PDC bits has the potential for greatly reducing the cost of exploratory drilling for oil and gas. Hard-rock PDC and improved impregnated-diamond bits will reduce cost in geothermal drilling, thus improving the economic feasibility of this renewable resource. Sandia and its collaborators are studying optimized, thermally stable, polycrystalline diamond bits that have high potential for downhole turbine and other high-speed drilling applications in geothermal, oil, and gas reservoirs.

4. Other Noteworthy Benefits

PDC drag bits now hold the three primary, all-time drilling records, as reported in Petroleum Engineering International (March 1999). The record single-run footage for a PDC bit is over 22,000 feet in the same well with no bit maintenance. The cumulative footage (with bit maintenance) for a single PDC bit is over 180,000 feet in 26 runs. The penetration-rate record is over 2,200 feet per hour. Such performances play a key role in maintaining a strong competitive advantage for U.S. manufacturers in the international drilling market.

Professionals in the drilling community have acclaimed the significance of Sandia's contributions to synthetic-diamond bit technology. For example, a paper describing details of Sandia's work on PDC bits in the June 1986 issue of *SPE Drilling Engineering* was recognized by K. K. Millheim, Executive Editor, as the "pick of the issue" (see *Supporting Materials*).

To date, Sandia researchers have produced over 30 conference papers, journal articles, and technical reports on PDC bit technology.

Benefiting from Sandia's technical inputs, advanced PDC bits hold all major drilling records in soft to medium-hardness formations.

SUPPORTING MATERIALS

"Sandia's Work on Advanced Hard-Rock Bits," Sandia National Laboratories Geothermal Program.

Falcone, Santa, "Technology Transfer Impact Profiles," School of Public Administration, University of New Mexico, November 1995.

Finger, J. T., and D. A. Glowka, "PDC Bit Research at Sandia National Laboratories" (SAND89-0079, June 1989).

Millheim, K. K.,"Executive Summary," *SPE Drilling Engineering*, Vol. 1, No. 3, June 1986, pp. 170–176.

Perdue, J. M., "1999 Drilling and Production Yearbook," *Petroleum Engineering International*, March 1999, pp. 43–55.